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Smart Metering and feedback systems: Suitable instruments to increase sustainable energy consumption?

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0. Abstract:

The issue of energy conservation has been around for at least 30 years now, flanked by numerous campaigns and scientific studies. And yet, rather than declining, energy consumption in private households has risen over the years – despite the fact that appliances have become increasingly energy-efficient. For this reason, both the political sector and social players continue to call for a reduction in consumption levels.

Due to the technology innovation of digital metering and the combination with ICT the provision of feedback on energy consumption towards household has gained significant attention among policy makers. European and German legislation has taken up already the idea to apply so called smart metering as an instrument to increase energy efficiency and adopted relevant laws.

In this paper the topic smart metering and feedback is drawn from two perspectives – legal and social scientific – and put into relation to each other.

From legal perspective the current relevant German legislation and their intentions towards market stipulation opens the picture. In a second step the perspective is changing towards the behaviour level of households. Recent European social scientific research results regarding feedback and energy consumption are introduced. Upon this empirical and theoretical base the critical issues from the perspectives of individual and household behaviour towards smart metering (as an instrument for sustainable energy consumption) are worked out.

In a synthesis the legal and behavioural perspectives are crossed and discussed whether the regulatory settings match with the intended targets. Also it can derived additional elements which could strengthen the concept “smart metering as a tool for sustainable energy consumption”.

1. Background

The limitation of the global mean temperature rise to maximal 2 ° C compared to pre-industrial times is one of the most central climate goals of the German Federal Government to conquer the consequences of the climate change. Against this backdrop some of the goals of the Federal Government include [1]:

- Reduce greenhouse gas emissions by 40 percent until 2020 toward 1990. According to the German Federal Environment Agency, Germany achieved a 21.3 percent reduction in 2007.

- Increase energy efficiency by 3 percent per year. This implies that primary energy can be used twice efficient in 2020 compared to 1990.

Private households build one pillar within the federal efforts of the climate protection. These efforts aspire a significant efficiency enhancement and energy saving.

The German Energy Agency (dena) [2] calculates on 28 percent of energy saving potential in German households. But there still exist a gap between the (perceived) importance of energy efficiency and the actually behaviour of the private households. The provision of information and recommendations are often seen as trigger of changes in the behaviour.

The technological innovation of digital meters in combination with different information and communication-technologies (ICT) have caught large attention among political and energy-economic stakeholders because through this innovation consumption of electricity can be feed backed in much shorter time to the private households than with the previous mechanical meter. The European and German Federal legislation has already integrated the so-called Smart Meter as an instrument to increase the energy efficiency by suitable law changes into her climate protection politics.

The saving effect by feedback is proved in many studies [3]. Moreover the latest results of research [4] suggest that the generated feedback information is interesting for the private households but not sufficient to change the consumer behaviour towards an environment-conscious use of energy. Similar appears the current state of research on variable Tariffs: Although the energy industry regards variable energy tariffs – as in the amendment of the Energy Industry Act (EnWG) postulated - as an instrument of motivation for the climate protection by the consumer, a study [5] shows that there exists a wide rejection in private households about variable energy tariffs.

These are obvious signs, that the existing efficiency potential of the private households can not suitably be integrated in the climate protection as the current approaches and instruments not yet become relevant in daily action of households. This paper shows the linkages and gaps between the current legislation and the dissemination of Smart Metering technology. In the dissemination of the technology the German households shall take in the role as pulling force. In the following critical points and outline attempts to a solution on basis of the previous social science research will be showed.

2. Smart Metering technology

„Smart Metering“ is the advanced intelligent metering of energy consumption with electronic metering reading of the consumption in small temporal intervals based on bidirectional communication which also allows automated or indirect management of loads according of economic or other criteria. Additionally following functions for energy service can be provided [6].

Smart Metering permits [7]:

1. Automated and remote metering reading
2. Information for the consumer (also possible for various energy sources „Multi Utility Metering“) on consumption, costs, CO_2 emissions, historical and actual data in comparison (Feedback)

3. Remote connection and blocking
4. Energy management of intelligent loads and appliances
5. Quality assurance by permanent monitoring, identification of power drops and power failures
6. Services for local energy feed-in

By using digital meters, which in future will serve all over Europe to monitor the energy consumption of private households at all times, new possibilities are arising to obtain a detailed and up-to-date data compilation. This will not only simplify billing for the utilities, but also provide consumers a precise data feedback on their energy consumption patterns by using visualisation and documentation. Many stakeholders share the expectation that based on this information it will be possible for households and small and medium enterprises to draw conclusions on how to save energy in the future.

Currently various technical concepts for Smart Metering are tested and pursuit. Here we can only give a very short description on components and possible structures [8]: The digital meter collects the energy consumption data and replace i.e. the mechanical Ferraris meters. The data concentration can be placed in the household to collect data from different energy sources or can be situated near a transformer point to concentrate the data from several hundred households. The data processing is normally offered by the service provider i.e. the utility or a metering company.

For marketable systems it is finally necessary that they offer a reliable bidirectional communication along all positions of the metering line. The communication infrastructure often must be adapted to local conditions and turned out to be most accident-sensitive in the system. Additionally communication between components of different suppliers often is not possible as standards are not (yet) defined and many suppliers use proprietary protocols.

Most common communication between meters, data concentrator and the data processing unit is Power Line Communication (PLC). In these cases the data concentrator is mostly in the nearest transformer station; from here the information is – due to the technical failure of PLC – transferred via mobile phone lines, radio (GSM/GPRS) or a wire based data transmission (i.e. DSL) to the data processing unit [9].

3. Legal framework

Two goals of the area wide introduction of the smart metering technology are pursuit by two different Federal ministries. On one side the discussion is characterized by the energy economic goal to liberalise the operation of measuring points. The environmental goal - an increase of energy efficiency in private households through consumption feedback and variable energy prices - gain more and more groundin the last two years.

3.1. Goals and framework for the liberalization of the operation of measuring points

The overall goal is the creation of a competitive market for intelligent meter systems, associatedproducts and services which will emerge if there is an attractive basic regular framework for the market participants to invest in innovative products.

The first political obligation was made moreover by the European ESD directive [10]. As a result in Germany the liberalisation - already begun in 2005 - of the measuring point company was extended by the opening of the market for automatic meter reading (EnWG in §21b). The explicit aim of the regulator is to open a market-driven process to a nationwide dissemination of intelligent meters for the initiated liberalisation in the metering market. Main actor is the market itself. The appropriate Measuring Access Order (in German “Messzugangsverordnung MessZV”) places conceptual on the greatest possible competition by most slightly possible restriction of the freedom of consumers and enterprises. The regulation consciously avoids obligations of a technical standard (incl. data format), technical least standards or equipment detail of intelligent meters and on the timeline to finalise the roll-out.

The opening for the competition should help to open advantages in price for the end consumer and technical innovations in the meter market as well as to promote concepts for smart grids. Furthermore the consumer should be moved into the situation to steer her own consumption better. It is an explicit aim of the regulator that after a period of six years of intelligent meters , preferably together with loading variable tariffs will be deployed all over the country, given an economic reasonability for the roll-out. Essential means for the opening of the market is the possibility of the power recipient to select a Metering Point Operator (MPO) resp. Measuring Service Provider (MSP) on his own preferences.

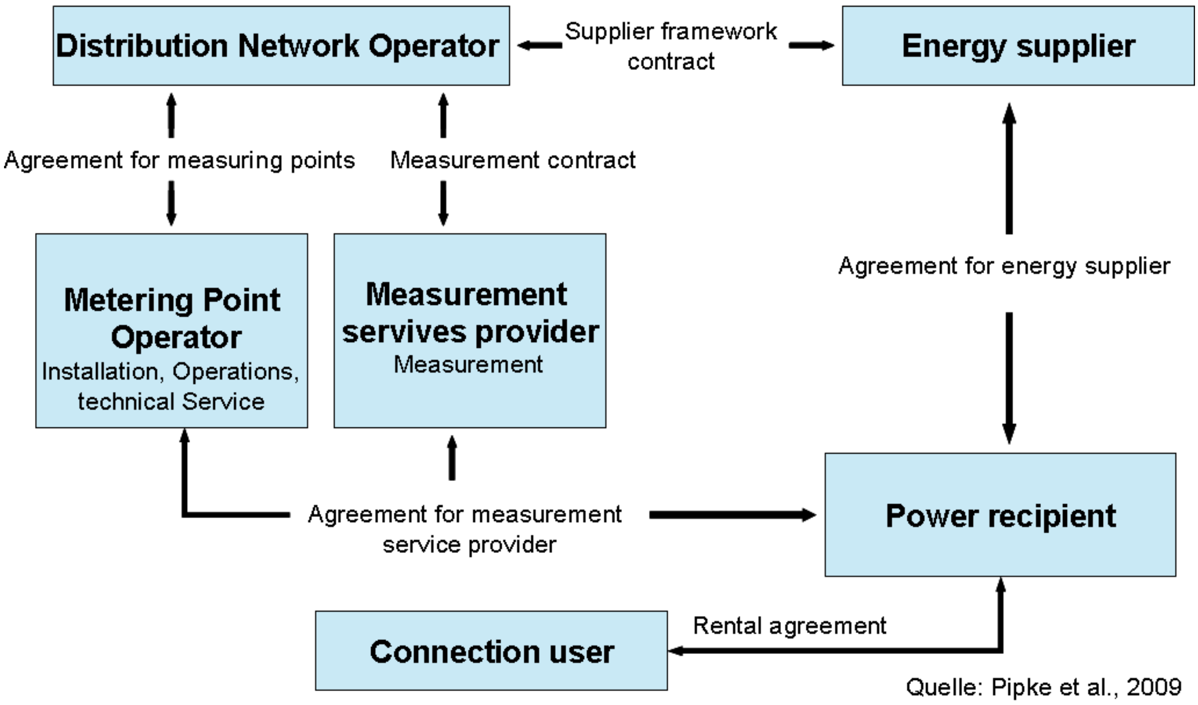

Figure 1: Contractual relations after the amendment of the Energy Industry Act (EnWG)/ Measuring Access Order (MessZV)

In the course of the liberalisation new market roles, those of the Measuring Service Provider and the Meter Point Operator were created. New contract relations between MPO/MSP and power recipient as well as between MPO/MSP and the distribution network operator become necessary (see figure 1).

Furthermore the distribution system operator has the role of a "basic provider" for metering and is responsible basically for metering point operation and measurement, as far as no other contractual arrangements are made by the power recipient. Also, the energy supply companies were obliged in the EnWG (§40) to display the remunerations for metering point operation and measurement on the calculation separately and to offer flexible tariffs to the end customers from the 30th of December, 2010 for electricity. This should give stimuli to the consumers to save energy.

In addition, the end consumer can require semi-annual or monthly billing instead the current annual billing from his energy supplier.

It is to be assumed that an economically efficient conversion of these legal obligations require the application of remote readable digital meters. Household energy consumption data are classified generally as personal data. Therefore the collection and circulation of consumption data falls under §28 of the Federal Data Protection Act.

4. Is the market pulling?

The driver for a nationwide roll-out of Smart Metering technology – accordingly to the current German legislative framework – will be the market. Here we can distinguish between the economic energy actors (utilities and new actors due to liberalisation) and the private energy actors (households). We will more detailed assess whether it can be expected that both will unfold their power under the current framework conditions to achieve the governmental target set.

4.1. Private households as a driver for a nationwide roll-out

The legislative attempt for the nationwide dissemination of Smart metering consists substantially in giving the competence to the power recipient to select a MPO (or MSP) on his own preferences. Behind this attempt lies the notion that electoral freedom is a need of the private power recipient. Often it is argued that the possibility of a higher temporal consumption feedback than presently with an annual meter reading will stipulate private households to make use of there new freedom. Another incentive to start searching the most appropriate MPO is seen in the economic benefit, that households can effect through own energy savings and increase of energy efficiency.

Therefore in this paper I want to question whether

- savings as an effect of feedback use can be expected
- the provision of information only are already enough or if some social scientific findings might help to strengthen the current framework approach

As well in brief an economic view on the current situation of the energy economic actors is thrown.

4.1.1. Energy savings through feedback

Household consumption studies over last years show a constant increase of energy consumption [11]. Though households report the interest to save energy [12] the investment in new appliances and the continued operation of old appliances in parallel lead to the so called rebound effect [13] - meaning the neutralisation of saving effects.

Among a variety of interventions to promote energy saving in private households feedback attracted constantly attention since the early 1970s in research and public. The effectiveness of feedback on energy consumption has been studied since more than three decades – utilizing a vast variety of feedback technologies. Psychological studies show that feedback determines the decrease of energy consumption. The effects of feedback on electricity consumption are summarized in three review papers.

Fischer [14] screened 26 studies on feedback from 11 countries in the years 1987 until 2007. She concentrated on studies which focused directly on feedback. According to her findings feedback led to energy savings between 5% and 12%.

Darby [15] reports energy savings between 5% and 15% for direct feedback, i.e. display of actual consumption on the meter or a screen. Between 0% und 10% have been attained with indirect feedback, which is processed information, mostly the electricity bill.

Abrahamse und Steg [13] reviewed 38 papers from 1977 until 2004 with several interventions promoting energy saving in households. In the case of feedback they confirm its effectiveness, which is stronger if it is provided frequently. The effects vary between households with low and high consumption. No variation is reported between the feedback of costs or ecological impacts, as well as for individual feedback or social comparison.

Most studies deal with effects through feedback and some with factors which influence the scale of effects [13]. Almost no study spots the mechanisms which lead to the effectiveness of feedback. Wilhite und Ling [16] request compatibility of the way of feedback display and the way how consumers analyse their consumption and take decisions for alternative consumption patterns. More insight in these psychological processes could help to optimize the technical part of the feedback system and develop it adequately to consumers needs – eventually specific for different target groups.

Behind this scientific request stands the question along which paradigm energy consumption and behavioural changes in households are understood. The main two – not necessarily contradictory – paradigms are presented in the following.

4.1.2. Paradigm of the analytic-rational household

Kempton und Layne [17] point out, that the consumers have considerable competence available to analyse their own energy consumption. To develop and use this competences they also refer to energy bills, comparisons with previous bills, comparisons with neighbours, own meter readings and weather observations if there is no feedback system available. The authors postulate that institutions (i.e. utilities) as well as consumers have specific strengths in the processing and analysis of energy consumption data. Figure 2 illustrates this idea. While utilities currently focus on the processing and transformation of metering data only, many energy saving programmes have spend much efforts in cause interpretation of individual households. For this they have to work through heterogen consumption and appliance data of households which both is costly and on behalf of the household often not desired. Kempton und Layne propose a more reasonable distribution of the data processing which should be oriented along the strengths of processing and analysis of the stakeholders. This implies that the inclusion of complementing information to the metering data as i.e. weather data is not a huge effort for the utility and could also be assessed by the utility in terms of deviation from historical, consumption. The cause interpretation and behavioural adaption has to be done individually as consumers know best which behaviour alternatives are useful and realistic. Acknowledge of individual and institutional strengths in analysis energy consumption data can be supported by various technology features of smart metering systems. Smart Metering systems provide information of energy consumption and can be seen as an antecedent intervention to change individual behaviour [18]. This information reflects the specific consumption of a household and can be displayed in almost every temporal detail. Through suitable functional and aesthetic displays user can select relevant information.

The processing of current and historical consumption data and functions like stand-by identification, identification of peak loads in the household [19] make digital meters smart towards the consumer.

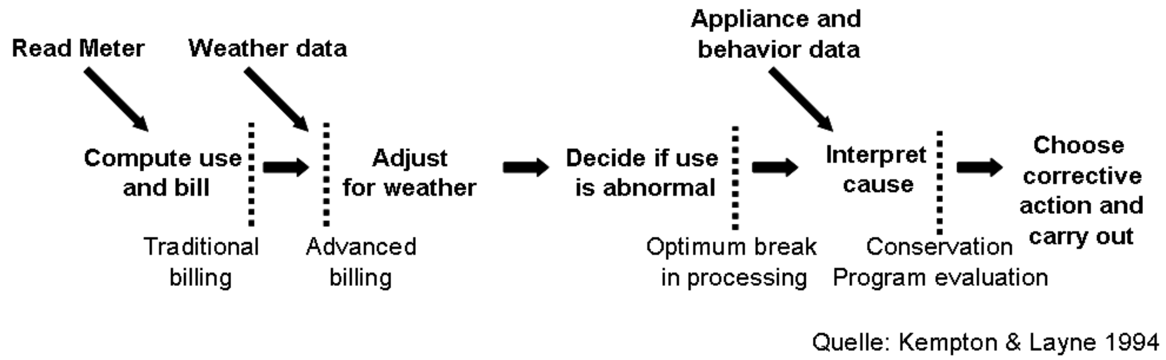

Figure 2: Energy data flow. Institutions begin processing at left of figure. Dotted lines represent the break between data processing by institution (to left of line) and processing by household (to right of line).

Because the information about the consumption is available to the users about a year (at least with the web portal) permanently, the web portal (with regular consultation) becomes a continuous feedback option. Through this the user can see the effect of her behavioural change like the effect with a continuation of present way of life.

According this paradigm it appears, that given the optimum level of energy consumption information households consequently use the information in a rational way – meaning starting to reduce when indicated.

4.1.3. Paradigm of daily life energy behaviour

Under this paradigm several social scientific streams are bound to support a realistic understanding of energy consumption behaviour. One major element of this paradigm includes habits – formed by repetitive activities performed in stable contexts [20]. They are an essential determinant of domestic energy consumption even though there is evident increase of awareness and concern about energy related environmental issues such as climate change. [21]. Habits are individually acquired and learned. They fulfil mainly the function to reduce cognitive efforts in daily life and mediate behaviour which has been successful in (earlier) repetitive situations. Habits are “automatic elicitation of behaviour upon encountering specific cues” [22]. Psychologically habits can be viewed as an optimised cognitive script or knowledge structure [23] which is generally accessible for changes.

As Maréchal [24] points out, the vulnerability of habits lies in their dependency on context and contextual cues which also offers a way forward for changing them. So the naturally occurring changes of contexts (as relocation, retirement or birth of a child) can provide “windows of opportunities” to change the optimised knowledge structure and adapt it to more consciously elaborated and used cognitive structures. During this “windows of opportunities” a rational choice based appraisal of its own energy consumption behaviour and its partly change seems under current scientific state reasonable as it is shown in other environmental behavioural areas [25].

So this perspective narrows the above described paradigm of the analytic-rational household but does not oppose it.

The second element of the paradigm of daily life energy behaviour is referring to the sociological understanding of household organisation and distribution of work which also has its impact on the acceptance and uptake of a technology innovation as Smart Metering.

Throughout the last century until today the spread of technology in German and European households [26] has increased. Still the mechanisation of households through the wide use of time and labour saving appliances did not lead to a proven reduction of labour time in the household – though household size decreased over the years. Even time savings account for some single work processes thanks to improved appliance technologies most studies about working time in households conclude, that household work has despite increasing mechanistaion of households not reduced in the last century [27]

The calculation of official statistics [28] illustrate this paradoxial development and prove that even in a modern society like Germany the percentage of unpaid work (as household and craft activities, care and honorary posts) is larger than paid work.

The amount of unpaid work varies strongly with gender and social status of the household members. The largest volume of unpaid work is carried out by women who have no own income, are married with an employed man and have children under 18 years. These women work in average 507 minutes a day – without payment. So it could be worth to ask who is the persons in the household who mainly deal with the household technology and also therefore could benefit from energy feedback information. We have to acknowledge that women – who are already busy all day without paid work as shown above - play a crucial role in the setting. From an exploratory study about Smart metering and energy feedback [29] it becomes obvious that the majority of interviewed persons do not have the motivation to approach feedback information with an analytic intention but would be keen to get quick practical recommendation for concrete behavioural changes.

Again a purely rational-analytic paradigm is properly neglecting the widespread need in many households for alleviation in daily life – in this case in the coping strategy for efficient energy use under the multiple requirements and priorities of household organisation and limited personal temporal and cognitive resources.

For useful feedback instruments from social scientific perspective one can conclude: It does not make sense to bombard people with just-in-time data, because it is barely possible to interpret them. Means of relating and comparing data at manageable intervals are attractive and helpful as a kind of benchmarking. The visualisation in graphs and the information in general must help consumers to make practical changes in their household situation. It makes sense to give a few but carefully selected and well-designed telling representations. Further it is an indispensable precondition for efficacy to have the possibility of (personal) electricity consultation and assistance in interpreting the feedback, along with pointers for possible action and energy-saving tips (energy-related advisory service).

So in general, it seems possible to create a certain pull force from private household actors, if a range of products, which meet the specific needs of clustered target groups, is available and matches with the characteristics of social and organisational circumstances.

Up to now, no systematic studies on these issues have been published. The German research project Intelliekon [30] will be able to give more insights in potential target groups, their needs, and preferences concerning energy consumption information and behaviour in the next year. Currently about 3000 households test for one year a web portal with individual household energy consumption data and energy saving recommendations, as well as a printed monthly energy consumption sheet, a in-house energy display and personal energy conservation advisory.

But also research can only study on the existence and potential of the acceptance and use of Smart metering services, the creation of successful technologies, products and services is certainly best performed and disseminated by business enterprises of the energy market.

4.2. Utilities as a driver for a nationwide roll-out

Besides private households the economic energy market actors like the utilities and grid operator companies contribute to a roll-out of Smart Metering technology. Their motivations to step in using the metering innovation are manifold [9] but depending largely on the return of their investments.

Three refunding possibilities are reasonable:

1. Along the legislation the remuneration for the deployment of intelligent meter systems by the distribution system operator can be refunded through the regulation fund. This coverage is around 10 – 20 % of the hardware costs of a digital metering system.
2. With the upbringing of innovative energy products for private households as energy feedback, in-house display, time of use tariffs etc. the pricing of the energy services will reflect to certain extend the investment costs of smart metering systems. But though no representative study yet is available, own unpublished non-representative studies indicate, that households have strong price sensitivity in the area of energy. Upon the current state of research it seems doubtful that private households pay a major part of the investment costs of smart metering costs – in a liberalised market they will tend prefer cheaper suppliers and metering point operator even if their services package is reduced.

3. The strongest economic argument for a roll-out currently is the optimisation of business processes within a utility and towards the (new) market players in the liberalised energy and metering market. Latest studies [30] show that a complete roll-out with several 10.000 metering points is economically feasible and financial viable only through the cost savings rewarded from process streamlining and optimisation. Critical here is that only a total roll-out to all customers and a straight development of communication and business IT infrastructure can achieve this goal. The operation of traditional metering systems in parallel with digital meters requires the operation and maintenance of at least two business IT systems with according process structures. Another critical point here is the energy supply market in Germany: more than 900 utilities share this market; many of them have less than 50.000 metering points in private households.

Through the legislative requirements which enforces distribution system operator to install – under specific conditions – digital electricity meters and the opening of the metering market the economic market actors face now a double risk. First they have to find the strategy for a sound financing of a large-scale roll-out with a technology which is still in dynamic development. Second they face the risk that a customer with a digital meter decides to change the metering point operator. Until now there is no experience whether in such case the new metering point operator is refunding the value of the digital meter or installs its own technology and forces the previous operator to uninstall its digital meter – causing above extra expenses for labour.

5. Conclusion and outlook

The awareness and motivation for sustainable energy consumption in households in Germany is widespread. Energy feedback (and other services) based on Smart Metering technology can increase the sustainability in energy use by reducing ineffective consumption (stand-by or inefficient appliances) and increase efficiency of electricity and thermal energy use if the services and products match with the divers social and organisational characteristics of German households.

From legislative perspective it is therefore promising to trust in free market principles, as it is the origin challenge of the utilities to offer products which catch the attention of their (potential) customers and renders them an advantage against their competitors.

Rather critical has to be seen, that legislation is requesting the roll-out of a technology by market actor along their business principles. The German government is expecting to fulfil their targets for climate protection and complete the liberalisation of the German energy market. As mentioned, also the utilities express several motivations to make use of Smart Metering technology but the current legislative framework does not encourage them to do so.

Besides the financial also technical risks have to be considered. The legislation explicitly avoids formulating any technical specifications or guidelines like a list of minimum functionalities or the opening of protocols on all communication layers. Through this gap it is nearly impossible have smart metering systems installed which are easily compatible with those of other manufacturers. As an analogy would be hundreds of different filler necks at a car tanks and fuel nozzles of petrol pumps: if there would be no standardisation of these two components for each car type and each service station driving the filling at different oil companies would be always require a technical adaptation of one or even both components.

So the current position of German utilities can be described as rather hesitating and waiting for first movers to begin the competition – and take the initial high risk.

The take up of technology innovations only through market pull works perfectly if strong rational or emotional reasons are given. Mobile phone or mp3 technology certainly are famous examples for this thesis. Many other innovations have been promoted and disseminated with intelligent subsidy structures which do not necessarily have to employ public budgets. The German feed-in law and feed-in tariff is one prominent example for a strong support mechanism without burdening the German federal budget.

Still the main driver for the nationwide roll-out of Smart Metering technology is the German government (complying with EU legislative) motivated to satisfy the societal interest of climate protection. This target itself can partly benefit from the nationwide use of intelligent, socially adapted smart metering services which can match with individuals' interests. But – as pointed out before – these interests are in the diversity of personal priorities and constraints to marginal that they can create a strong market pull which soften the technical and financial risks of the economic energy actors.

To create a market dynamic the technical and financial boundaries have to be adjusted. In terms of a legislative instrument the coverage of a financial incentive for the private households for the initial installation of a smart metering system could give a huge push to the whole market, as utilities and new market players would quickly have to step into the competition for their customers.

This push can be even increased if basic technical conditions are set; again here seems mainly the communication compatibility between different manufacturer systems important. If a certain market dynamic is established a further technical standardisation and specification will follow from the market actors itself.

To conclude in terms of the contribution towards sustainability, it seems that the creation of a (economic) sustainable legislative framework for the dissemination of smart metering can indeed contribute to an environmental sustainability.

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